

CONSTRUCTION OF FOLIAR KEY AND PHYLOGENETIC TREE FOR 114 HERBAGE VEGETABLES: A GLOBAL STUDY

BALAMANI VENKATA ANNAPURNA GORTH¹ & RASAJNA NADELLA²

¹Department of Botany, Government Autonomous College, Rajamahendravaram, Andhra Pradesh, India

²Assistant Professor, Department of Biotechnology, Sri Padmavathi Mahila Visvavidyalayam,

Tirupati, Andhra Pradesh, India &

National Council of Science and Technology (CONACyT), Institute of Neuroethology, Mexico

ABSTRACT

The term vegetable is usually applied to edible plants which store up reserve food which is eaten cooked or raw as the salad. Even though, a balanced diet requires ten ounces of vegetables per adult per a day, the present availability is only 1.3 ounces per adult per a day. To increase the consumption of vegetables, we must know about the various types of vegetables along with their identification. So, the present paper deals with the study of herbage vegetables that are distributed over 114 species belonging to 84 genera and 41 families. This knowledge of herbage vegetables would be of great use to business (restaurant) people and also to the researchers in the fields of herbal medicine, botany, biosystematics, taxonomy, Ayurveda, homeopathy, pharmaceuticals, and nutraceuticals.

KEYWORDS: Taxonomy, Dichotomous, Indented Key, Therapeutic, Geographic Distribution & Inflorescence

Received: May 28, 2018; **Accepted:** Jun 18, 2018; **Published:** Jul 16, 2018; **Paper Id.:** IJBRAUG20182

1. INTRODUCTION

The primary necessities of man are threefold – food, clothing and shelter. To fulfill his three folds, man uses the knowledge of botany. The food we eat primarily comes from plants in the form of cereals, millets, pulses, vegetables and fruits. Among these five, daily consumed food normally includes cereals, pulses and vegetables; Cereals for starch, pulses for protein and vegetables for minerals and vitamins. For clothing, he depends on the fiber yielding plants. For shelter, he depends on the timber yielding plants for the construction of the house. So, it becomes quite evident that knowledge of botany and its proper application lead to the well-being of humanity in several ways.

The term vegetable is usually applied to the edible plant parts which store up reserve food in roots, stems, leaves, vegetative buds, floral buds and fruits, which are eaten cooked or raw as a salad. Rimando simply defined vegetables as “crops usually grown for culinary purposes”. The nutritive value of vegetables is tremendous because of the presence of indispensable mineral salts and vitamins (Rimando, 2004). For a balanced diet, more and more utilization of vegetables is necessary. So, clear-cut knowledge on more types of vegetables is necessary. According to Hill, the vegetables can be grouped into three broad classifications based on their botanical parts that are edible and their location with respect to the ground (Hill, 1972). These include (1) Earth / underground vegetables are those in which the edible plants are below the ground including modified roots and stems; (2) Herbage vegetables are those with aboveground/aerial parts including stems, leaves, buds, flowers and inflorescence and (3) Fruit

vegetables are those in which the botanical fruits are usually cooked and rarely eaten raw except in salads.

Based on ethnobotanical studies, more number of herbage vegetables can be known from nature either weedy or cultivated plants. Most of the herbage vegetables that are known to mankind include leafy vegetables, which should be collected before flowering. The best advantages of cultivating herbage vegetables is that they have short harvesting time of few weeks, easily cultivated even on a terrace, grown all through the year, most of them are grown near the waste water and no much care is necessary for their growth. So, with less care, hard work and time, we can get high yields. The best time to collect all the herbage vegetables is in the evening times as plant stores energy from sunlight, a process known as photosynthesis, during daytime and at the night utilizes the stored food material.

Herbage vegetables are rich in water and proteins, sufficient amount of mineral salts and vitamins and a smaller amount of digestible carbohydrates. Hence, the herbage vegetables make an essential part of human diet. Hardly 10-15 types of herbage vegetables are in common use in cities and around 30 types of herbages in villages that are consumed by the local people. Most of the herbage vegetable consumption knowledge comes from traditional culinary practices and also from forefathers that pass from generation to generations.

The present study deals with the geographical distribution, parts used for the culinary purpose, identification by foliar key and phylogenetic tree construction of 114 herbage vegetables around the world. Our paper is the best source to identify and on keen observation of the paper, one can start consuming all or most of the herbage vegetables for the well-being and healthy mankind.

2. MATERIALS AND METHODS

2.1 Plant Collection from the Field

All the herbage vegetables that were edible globally were first listed (M. Venkaiah, 2010; Pandey, 2005; Rao, 1999) from various sources such as books, internet and from the data given by the local people. Altogether we listed 114 plants and their edible part (table 1), which are easy to grow and are readily available almost all through the year. Plant material collection was done from the fields as mentioned elsewhere (Rasajna, 2017a, 2017b). All the plants were grown in loam soiled pots at the suitable environment with a continuous supply of air, water and sunlight.

Table 1: Table showing the Number of Herbage Plants that belong to their Corresponding Family and Herbage Edible Part Used

Part / type of Herbage Part used	Class/Sub Class	Families	Name of the Plant	No. of Genus	No. of Species	Total No. of Herbage Plants / Part Used
Normal stem	Monochlamydae	Chenopodiaceae	<i>Salicornia brachiata</i> Roxb.	01	01	02
	Polypetalae	Vitaceae	<i>Cissus quadrangularis</i> L.	01	01	
Modified stem	Polypetalae	Brassicaceae	<i>Brassica oleracea</i> L. var. <i>gongylodes</i> L.	01	01	02
		Cactaceae	<i>Opuntia ficus-indica</i> Mill.	01	01	
Vegetative buds	Polypetalae	Asteraceae	<i>Lactuca sativa</i> L.	01	01	04
	Gamopetalae	Brassicaceae	<i>Brassica oleracea</i> L. var. <i>capitata</i> <i>Brassica oleracea</i> var. <i>capitata</i> f. <i>rubra</i> L.	01	02	
	Monocots	Liliaceae	<i>Asparagus officinalis</i> L.	01	01	
Inflorescence	Monocots	Musaceae	<i>Musa sapientum</i> L.	01	01	01

axis/pseudo stem						
Immature inflorescence	Polypetalae	Brassicaceae	<i>Brassica oleracea</i> L. var. <i>botrytis</i> <i>Brassica oleracea</i> var. <i>italica</i> L.	01	02	04
	Gamopetalae	Asteraceae	<i>Cynara cardunculus</i> var. <i>scolymus</i> L.	01	01	
	Monocots	Musaceae	<i>Musa sapientum</i> L.	01	01	
Flowers/Flowers of Mature inflorescence/ Flower buds	Polypetalae	Brassicaceae	<i>Alliaria petiolata</i> (M.Bieb.) Cavara & Grande	01	01	12
		Caesalpinaceae	<i>Bauhinia variegata</i> L.	01	01	
		Capparidaceae	<i>Capparis spinosa</i> L.	01	01	
		Fabaceae	<i>Sesbania grandiflora</i> (L.) Poiret. <i>Trifolium pratense</i> L.	02	02	
		Malvaceae	<i>Hibiscus sabdariffa</i> L. <i>Malva sylvestris</i> L.	02	02	
		Meliaceae	<i>Azadirachta indica</i> A.Juss	01	01	
		Nymphaeaceae	<i>Nymphaea odorata</i> Aiton	01	01	
	Gamopetalae	Asteraceae	<i>Cichorium endivia</i> L.	01	01	
	Monochlamydae	Amaranthaceae	<i>Celosia argentea</i> L.	01	01	
	Monocots	Asphodelaceae	<i>Hemerocallis lilioasphodelus</i> L.	01	01	
Leaves	Polypetalae	Aizoaceae	<i>Gisekia pharnaceoides</i> L. <i>Glinus oppositifolius</i> (L.) Aug. DC. <i>Sesuvium portulacastrum</i> (L.) L. <i>Tetragonia tetragonoides</i> (Pallos) Kuntz <i>Trianthema decandra</i> L. <i>Trianthema portulacastrum</i> L.	05	06	
		Apiaceae	<i>Anethum graveolens</i> L. <i>Apium graveolens</i> L. <i>Centella asiatica</i> (L.) Urban <i>Coriandrum sativum</i> L.	04	04	
		Brassicaceae	<i>Alliaria petiolata</i> (M.Bieb.) Cavara & Grande <i>Brassica hirta</i> Moench. / <i>Sinapis alba</i> L. <i>Brassica juncea</i> (L.) Czern. <i>Brassica oleracea</i> L. var. <i>acephala</i> DC. <i>Brassica oleracea</i> L. var. <i>gemmifera</i> Zenk. <i>Brassica rapa</i> subsp. <i>Pekinensis</i> <i>Brassica rapa</i> var. <i>perviridis</i> <i>Brassica rapa</i> var. <i>rapa</i> L. <i>Eruca sativa</i> Mill.	05	11	

			<i>Nasturtium officinale</i> W.T.Aiton <i>Raphanus sativus</i> (L.) Domin			98
		Caesalpinaceae	<i>Bauhinia variegata</i> L. <i>Cassia angustifolia</i> M.Vahl <i>Cassia fistula</i> L. <i>Cassia tora</i> / <i>Senna tora</i> (L.) Roxb. <i>Tamarindus indica</i> L.	03	05	
		Caprifoliaceae	<i>Valerianella locusta</i> (L.) Betcke	01	01	
		Capparidaceae	<i>Cleome gynandra</i> L.	01	01	
		Fabaceae	<i>Sesbania grandiflora</i> (L.) Poiret. <i>Trifolium repens</i> L. <i>Trigonella corniculata</i> (L.) L. <i>Trigonella foenum-</i> <i>graecum</i> L.	03	04	
		Geraniaceae	<i>Geranium robertianum</i> L.	01	01	
		Malvaceae	<i>Hibiscus cannabinus</i> L. <i>Hibiscus furcatus</i> Willd. <i>Hibiscus sabdariffa</i> L. <i>Malva sylvestris</i> L.	02	04	
		Mimosaceae	<i>Acacia concinna</i> (Willd.) DC.	01	01	
		Montiaceae	<i>Claytonia perfoliata</i> Donn ex Willd.	01	01	
		Moringaceae	<i>Moringa oleifera</i> Lam.	01	01	
		Nymphaeaceae	<i>Nymphaea odorata</i> Aiton	01	01	
		Oxalidaceae	<i>Oxalis corniculata</i> L.	01	01	
		Portulacaceae	<i>Portulaca oleracea</i> L. <i>Portulaca quadrifida</i> L. <i>Talinum triangulare</i> (Jacq.) Willd.	02	03	
		Rutaceae	<i>Murraya koenigii</i> (L.) Spreng	01	01	
		Sapindaceae	<i>Cardiospermum</i> <i>halicacabum</i> L.	01	01	
		Saururaceae	<i>Houttuynia cordata</i> Thunb.	01	01	
		Tiliaceae	<i>Corchorus capsularis</i> L.	01	01	
		Vitaceae	<i>Cissus quadrangularis</i> L.	01	01	
	Gamopetalae	Asteraceae	<i>Achillea millefolium</i> L. <i>Cichorium intybus</i> L. <i>Eclipta alba</i> (L.) L. <i>Taraxacum officinale</i> (L.) Weber ex. F.H.Wigg	04	04	
		Convolvulaceae	<i>Ipomea reptans</i> Poir. / <i>Ipomea aquatica</i> Forsskal	01	01	
		Lamiaceae	<i>Coleus amboinicus</i> / <i>Plectranthus amboinicus</i> (Lour.) Spreng. <i>Glechoma hederacea</i> L.	05	05	

			<i>Leucas aspera</i> (Willd.) L. <i>Mentha arvensis</i> L. <i>Ocimum tenuiflorum</i> L./ <i>Ocimum sanctum</i> L.			
		Rubiaceae	<i>Canthium dicoccum</i> (Gaertn.) Merr.	01	01	
		Solanaceae	<i>Solanum nigrum</i> L. <i>Solanum trilobatum</i> L.	01	02	
	Monochlamydae	Amaranthaceae	<i>Achyranthes aspera</i> L. <i>Aerva lanata</i> (L.) Juss. ex Schult. <i>Allmania nodiflora</i> (L.) R.Br. ex Wight <i>Alternanthera pungens</i> Kunth <i>Alternanthera sessilis</i> (L.) R.Br. ex DC. <i>Amaranthus blitum</i> L. <i>Amaranthus cruentus</i> L. <i>Amaranthus dubius</i> Mart. ex Thell. <i>Amaranthus palmeri</i> S. Wats. <i>Amaranthus spinosus</i> L. <i>Amaranthus tricolor</i> L. / <i>Amaranthus gangeticus</i> L. <i>Amaranthus viridis</i> L. <i>Celosia argentea</i> L. <i>Digera muricata</i> (L.) Mart.	07	14	
		Basellaceae	<i>Basella alba</i> L. <i>Basella rubra</i> L.	01	02	
		Chenopodiaceae	<i>Atriplex hortensis</i> L. <i>Chenopodium album</i> L. <i>Spinacia oleracea</i> L. <i>Suaeda maritima</i> (L.) Dumort. <i>Suaeda monoica</i> Forssk. Ex J.F.Gmelin	04	05	
		Euphorbiaceae	<i>Acalypha indica</i> L. <i>Sauropus androgynus</i> (L.) Merr.	02	02	
		Nyctaginaceae	<i>Boerhavia diffusa</i> L. nom. Cons. <i>Mirabilis expansa</i> (Ruiz & Pav.) Standl.	02	02	
		Piperaceae	<i>Piper betle</i> L.	01	01	
		Polygonaceae	<i>Antigonon leptopus</i> Hook. & Arn. <i>Rheum rhabarbarum</i> L. <i>Rumex vesicarius</i> L.	03	03	
	Monocots	Araceae	<i>Colocasia antiquorum</i> Schott	01	01	
		Commelinaceae	<i>Commelina benghalensis</i> L.	01	01	
		Liliaceae	<i>Allium cepa</i> L.	01	01	
		Poaceae	<i>Bambusa vulgaris</i> Schrad.	02	02	

			ex J.C. Wendl. <i>Cynodon dactylon</i> (L.) Pers.			
	Pteridophyta	Marsileaceae	<i>Marsilea quadrifolia</i> L.	01	01	

2. 2 Construction of Taxonomic Dichotomous Foliar keys

A taxonomic dichotomous key was constructed as mentioned elsewhere (Rasajna, 2017a). Dichotomous (di-two, chotomy-forked) key is most common that consist of a series of paired statements, termed couplets, which describe some feature of the plant. The two characters of the couplets are known as leads, which are mutually exclusive (Sambamurthy AVSS, 2005). Indented or yoked keys indents the leads of the couplet an equal distance from the left margin (Griffing, 2011). We began with the first couplet and selected the statement that best fits our specimen, which then directed us to another couplet and ultimately helped us in generating the key and as this key was generated mainly basing on the leaf characters, it is termed as a foliar key and thus the final identification of our herbage plants was done using the generated foliar key.

2. 3 Construction of Phylogenetic Tree

Phylogenetic tree was generated by computers using bioinformatics. We first entered all the scientific names of the plants in National center for biotechnology information (NCBI) taxonomy homepage and constructed a taxonomy common tree. After construction, the data was saved in phylip tree format with.phy file extension. This saved file was uploaded in PhyloDendron – phylogenetic tree printer, an online or offline software program PHY.FI (Fredslund, 2006). Once we upload and choose phenogram as our interested tree style to be constructed, the resultant phenogram can be downloaded in our desired format.

3. RESULTS

3. 1 General Identification and Grouping of Herbage Vegetables

All the 114 plants were observed and were identified as those herbage plants that were distributed among five classes as Polypetalae, Gamopetalae, Pteridophyta, Monochlamydae and monocots (Figure 1, A). Among the selected 114 for this study, maximum (45 %) herbage plants belong to the class Polypetalae whereas the minimum (1 %) belongs to Pteridophyta (Figure 1, A). Similarly, herbage plants with the edible part used other than leaves were also shown (Figure 1, B). Next to the leaves, the most common edible part used among the herbage vegetables include flowers/inflorescence (45 %), followed by buds (31 %) and the least include stem (24 %), including modified stem (Figure 1, B).

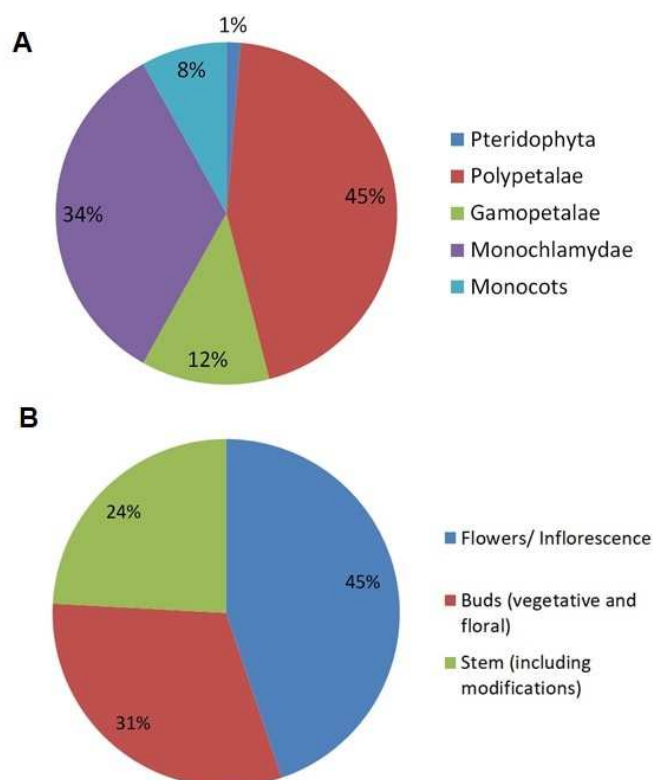


Figure 1: Distribution of Herbage Vegetables

The distribution of 114 herbage vegetables into various classes (A) and the edible part other than leaves (B).

3. 2 Taxonomic Identification of Herbage Plants by Constructing Dichotomous Foliar Key

For the proper identification of plants, we constructed and used an indented type of dichotomous key (Figure 2) that is commonly based on gross morphological features and characteristics that are readily observable in the field. The first lead of the first couplet, leaves are centric, helped us to identify the rounded type of leaf symmetry containing herbage plant *Allium cepa*; leaving all the bilateral leaf symmetry containing herbage plants with the second lead of the first couplet, leaves are not centric (Figure 2). Among the bilateral leaf symmetry containing herbages, we have identified all the 113 basing on 112 couplets and 224 leads. So, in total, the identification of 114 herbage vegetables using dichotomous foliar key was possible using 113 couplets and 226 leads (Figure 2).

1. Leaves are centric – *Allium cepa*
2. Leaves are not centric
3. Leaves are with open dichotomous venation – *Marsilea quadrifolia*
2. Leaves are not with open dichotomous venation
3. Leaves are modified into spines – *Opuntia ficus-indica*
4. Leaves are not modified into spines – *Asparagus officinalis*
5. Leaves are modified into scales, aerial stem is edible – *Salicornia brachiata*
3. Leaves are not modified
6. Leaves are with parallel venation
7. Leaves are large with parallel venation
8. Leaves are oblong with cinnose tip – *Musa sapientum*
9. Leaves are hastate with acute tip – *Colocasia antiquorum*
9. Leaves are not large with palmate parallel venation
10. Leaves are linear with sessile stem – *Cynodon dactylon*
9. Leaves are not linear, not with sessile stem
10. Leaves are lanceolate, with entire margin – *Bambusa vulgaris*
11. Leaves are not lanceolate, with or without entire margin
11. Leaves are ovate with entire margin – *Hemerocallis fillosophodelus*
11. Leaves are ovate with undulate margin – *Commelina benghalensis*
6. Leaves are with reticulate venation
12. Leaves are with axillary spines
13. Leaves are ovate, acuminate, herbaceous – *Amaranthus spinosus*
14. Leaves are elliptic, thick, alternately arranged – *Capparis spinosa*
14. Leaves are elliptic, thick, oppositely arranged – *Canthium diocicum*
15. Leaves are without axillary spines
15. Leaves are compound
16. Leaves are pinnate compound
17. Leaves are unipinnate compound
18. Leaves are imparipinnate, terminal leaflet is one
19. Base of the leaflet is asymmetrical, falcate with dentate margin – *Azadirachta indica*
20. Base of the leaflet is symmetrical, ovate with entire margin – *Murraya koenigii*
20. Leaves are bipinnate, terminal leaflets are two
20. Leaflets are small and oblong – *Tamarindus indica*
21. Number of leaflets per a leaf are more than 3 pairs
21. Number of leaflets per a leaf are 2-3 pairs – *Cassia tora*
22. Leaflets are linear lanceolate with entire margin – *Cassia angustifolia*
22. Leaflets are linear lanceolate with undulate margin – *Cassia fistula*
17. Leaves are not unipinnate compound
23. Leaflets are with 2 leaf base
24. Leaflets are small, oblong, small spines are present on the primary and secondary rachis – *Acacia concinna*
24. Leaflets are not so small, oblong, small spines are absent on the primary and secondary rachis – *Sebania grandiflora*
23. Leaves are not bipinnate, with or without pulvinous leaf base
25. Leaves are tripartite compound
26. Leaflets obovate with pulvinous leaf base – *Moringa oleifera*
26. Leaflets linear without pulvinous leaf base – *Achillea millefolium*
25. Leaves are decomposed
27. Leaflets are linear so appeared as dissected leaves – *Anethum graveolens*
27. Leaflets are not linear so not appeared as dissected leaves
28. Rachis stout, leaflets ovate not tender – *Apium graveolens*
28. Rachis not stout, leaflets ovate tender – *Coriandrum sativum*
16. Leaves are palmate compound
29. Leaves are trifoliate compound
30. Leaflets are 3 and pinnatifid – *Geranium robertianum*
30. Leaflets are 3 and not pinnatifid
31. Leaflets are ovate with dentate margin – *Cardiospermum halicacabum*
31. Leaflets are not ovate, not with dentate margin
32. Leaflets are obovate with emarginate tip – *Oxalis corniculata*
32. Leaflets are not obovate and not with emarginate tip
33. Leaflets are with white patches on the dorsal side, the 2 lateral leaflets are smaller in size than the central one
33. Leaflets are with hairy surface and acute tip – *Trifolium pratense*
34. Leaflets are not with hairy surface and with retuse tip – *Trifolium repens*
35. Petioles are green, leaflets are almost equal in size
35. Petioles are greenish red, leaflets with slightly dentate margin – *Trigonella corniculata*
29. Leaves are pentafoliate compound – *Cleome gynandra*
15. Leaves are simple
36. Base of the lamina is asymmetrical
37. Leaves are lobed, thick with acute tip – *Solanum trilobatum*
37. Leaves are not lobed, ovate, tender with acuminate tip – *Solanum nigrum*
38. Base of the lamina is symmetrical
39. Branches are condensed and appear as compound leaves
39. Leaves are small, obovate, alternately arranged – *Pyxianthus emblica*
39. Branches are not condensed and do not appear as compound leaves
40. Leaves are with palmate reticulate venation
41. Leaves are palmatifid with divergent palmate reticulate venation
42. Stem and petioles are green in color
43. Leaves are pentafid, covered with hairs – *Hibiscus cannabinus*
43. Leaves are tri or pentafid, not covered with hairs – *Hibiscus furcatus*
42. Stem and petioles are not green in color
44. Purple color is extended to the midrib of the leaves – *Hibiscus sabdariffa*
44. Purple color is not extended to the midrib of the leaves
45. Purple color is extended only to the base of the lamina – *Melva sylvestris*
45. Purple color is present only in the petioles – *Rhusum rhubarbarum*
46. Leaves are palmatifid, divergent or convergent, palmate reticulate venation
46. Leaves are reniform
47. Leaves with dentate margin – *Croton tigliatus*
47. Leaves with dentate margin – *Glechoma hederacea*
48. Leaves are elliptic, not thick, covered by waxy layer – *Nymphaea odorata*
48. Leaves are not aquatic, thick, not covered by waxy layer – *Claytonia perfoliata*
49. Leaves are not rotund or circular
50. Leaves are ovate, dark green in color, obtuse tip – *Nasturtium officinale*
50. Leaves are not ovate, not green in color
51. Leaves are cordate, herbaceous
52. Leaf margins are pink in color – *Houttuynia cordata*
52. Leaf margins are not pink in color
53. Leaves are cordate or ovate, not herbaceous
53. Leaves are not aromatic and not with adhesive roots at the nodes of the stem – *Piper betle*
54. Leaves are small with short petioles, serrate margin – *Cissus quadrangularis*
54. Leaves are not small with long petioles, serrate margin – *Rumex vesicarius*
40. Leaves are with pinnate reticulate venation
55. Leaves are pinnatifid – *Taraxacum officinale*
55. Leaves are not pinnatifid
56. Leaves are arranged in leaf mosaic manner – *Acalypha indica*
56. Leaves are not arranged in leaf mosaic manner
57. Leaves are in opposite phyllotaxy
58. 4 leaves are present at each node
59. Leaves are dull green, lanceolate with pinkish stem – *Glaskia pharnaceoides*
58. 2 leaves are present at each node
58. 2 leaves are present at each node – *Glinus oppositifolius*
60. 2 leaves are equal at each node
60. 2 leaves are equal at each node – *Boerhavia diffusa*
61. Leaves are opposite
62. Leaves are thick and coriaceous – *Coleus amboinicus*
62. Leaves are not thick and not coriaceous
63. Leaves are hairy, ovate with dentate margin – *Ocimum sanctum*
63. Leaves are glabrous, ovate with entire margin – *Mentha arvensis*
61. Leaves are not aromatic
64. Leaves are sessile or sub-sessile
65. Leaves are elliptic ovate
65. Leaves are covered with white powder – *Aerva lanata*
66. Leaves are not covered with white powder – *Alternanthera pungens*
65. Leaves are lanceolate
67. Leaves and plant parts are hairy and reddish green – *Althemia nodiflora*
67. Leaves and plant parts are glabrous and green – *Alternanthera sessilis*
64. Leaves are petiolate
68. Stem is round, leaves are cordate, tip is acute
69. Leaves are unequal at each node – *Mirabilis expansa*
69. Leaves are equal at each node – *Tetragonia tetragonioides*
68. Stem is angular, leaves are lanceolate, tip is acute
70. Leaves are with rough hairs – *Eclipta alba*
70. Leaves are with smooth hairs – *Leucas aspera*
57. Leaves are with alternate or opposite phyllotaxy
71. Leaves are succulent or mucilaginous
72. Leaves are fleshy and opposite
73. 2 unequal leaves are present at each node
74. Leaves are purplish green in color – *Trianthema portulacastrum*
74. Leaves are green in color – *Trianthema decandra*
73. 2 equal leaves are present at each node
75. Leaves are obovate
76. Succulent leaves are present on greenish red stems – *Sesuvium portulacastrum*
76. Succulent leaves are present on reddish transparent stems – *Portulaca oleracea*
75. Leaves lanceolate with white circle of hairs at the base, 4 equal leaves are present at each node – *Portulaca quadrifida*
72. Leaves are fleshy and alternate
77. Leaves are tubular, fleshy
78. Leaves are fruticose – *Suaeda maritima*
78. Leaves are monostichous – *Suaeda monoica*
77. Leaves are not tubular, not fleshy
79. Leaves are present on erect stem
80. Leaves are obovate with mucronate tip – *Talinum triangulare*
80. Leaves are not obovate and not with mucronate tip
81. Leaves are with long petioles – *Spiraea oleracea*
81. Leaves are with short petioles – *Atriplex hortensis*
79. Leaves are present on weak stems
82. Stem is green with green leaves – *Basella alba*
82. Stem is purple with purplish green leaves – *Basella rubra*
72. Leaves are not fleshy and alternate
83. Leaves are ovate
84. Leaves are emarginate tip – *Bauhinia racemosa*
84. Leaves are not with emarginate tip
85. Leaf tip is retuse – *Amaranthus blitum*
85. Leaf tip is not retuse
86. All plant parts are not red in color
87. Central portion of the lamina surface is dark red in color and peripheral surface is green in color – *Amaranthus tricolor*
87. Lamina surface is completely green in color
88. Stem and petioles are red in color
89. Leaves with long petioles, elliptic lanceolate with acuminate tip – *Amaranthus palmeri*
89. Leaves with short petioles, leaves ovate lanceolate – *Amaranthus dubius*
88. Stem, petioles, leaves – all are green in color
90. Leaves are not rhomboidal, with or without acute tip
90. Leaves are rhomboidal with acute tip – *Amaranthus viridis*
91. Leaves are not undulate margin
91. Leaves are ovate elongate and not with undulate margin – *Digera muricata*
92. Leaves are ovate with dentate margin – *Chenopodium album*
92. Leaves are ovate and not with dentate margin
93. Leaves are ovate elongate, with entire margin – *Celosia cristata*
94. Leaves are not ovate elongate and not with entire margin
94. Leaves are with serrate margin – *Corchorus capsularis*
94. Leaves are not with serrate margin
95. Leaves are bright green in color with acute tip – *Brassica hirta*
95. Leaves are dark green in color with acuminate tip – *Astiraceta petiolata*
95. Leaves are hastate with entire margin – *Ipomea reptans*
83. Leaves are not ovate
97. Leaves are spatulate
98. Leaves are with long petioles – *Brassica juncea*
98. Leaves are not with long petioles
99. Lamina ends with obtuse tip with prominent veins in the lamina – *Brassica rapa var. perrivida*
99. Lamina ends with obtuse tip with not prominent veins in the lamina – *Valerianella locusta*
97. Leaves are not spatulate, leaves are bracte
100. Leaves are edible
101. Lamina of the leaf ends with obovate shape with acute tip – *Raphanus sativus*
102. Leaf margin is with much folded lamina – *Brassica oleracea var. acephala*
102. Leaf margin is not with much folded lamina
103. Lamina is expanded with dentate margin – *Brassica rapa*
103. Lamina is elongate margin
104. Lamina is elongated into lanceolate with acute tip – *Cichorium intybus*
104. Lamina is elongated into lanceolate with obtuse tip – *Eruca sativa*
100. Edible parts are not only matured leaves but also stem, vegetative and floral buds are edible
105. Aerial stem is not edible – *Brassica oleracea var. gongylodes*
106. Vegetative buds are edible
107. Single terminal bud is edible
108. Young leaves of the vegetative buds are red in color – *Brassica oleracea var. capitata forma rubra*
108. Young leaves of the vegetative buds are green in color
109. Edible bud is elliptic in shape – *Brassica oleracea var. pabikensis*
109. Edible bud is globose in shape
110. Young leaves cover the terminal bud compactly – *Brassica oleracea var. capitata*
110. Young leaves do not cover the terminal bud and so bud is open – *Lactuca sativa*
107. Number of axillary buds and leaves are edible
111. Small axillary buds and leaves are edible – *Brassica oleracea var. gemmifera*
111. Bleached axillary buds and leaves are edible – *Cichorium endivia*
106. Only floral buds are edible
112. Immature edible inflorescence is head – *Cynara cardunculus*
112. Immature edible inflorescence is compound umbel
113. Edible inflorescence is in cream color – *Brassica oleracea var. botrytis*
113. Edible inflorescence is in green color – *Brassica oleracea var. italica*

Figure 2: Generation of the Taxonomic Dichotomous Indented Foliar key

A dichotomous indented foliar key was constructed for the characteristic identification of all the listed 114 herbage vegetables.

3.3 Construction of Cladogram

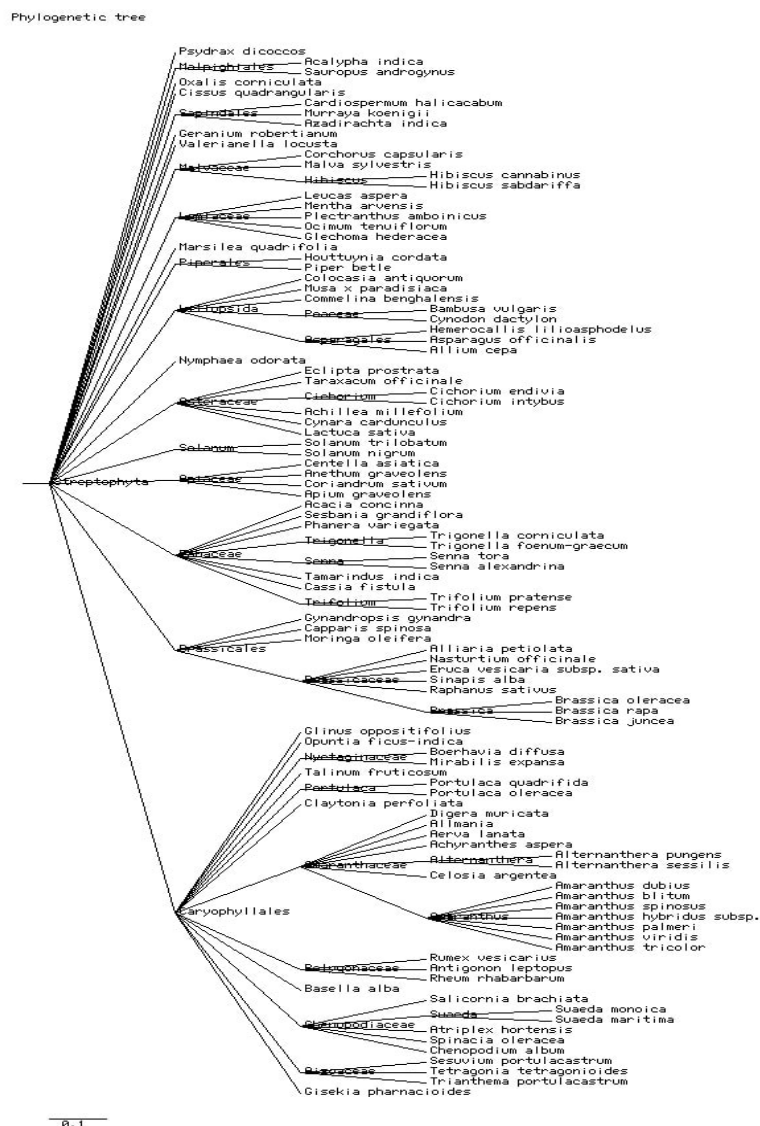


Figure 3: Construction of Cladogram

A rooted type of cladogram was constructed that helps in finding the phylogenetic and ancestral relationships among all the listed 114 herbage vegetables.

The cladogram shows us the phylogenetic and ancestral relationships among all the 114 herbage plants that were selected for our present study (Figure 3). We represented the phylogeny of all the herbage vegetables in the form of a cladogram, a rooted tree in which all the herbage vegetables share a common ancestor known as the root (Figure 3). In this type of tree, there exists a particular root node which represents a speciation event in evolution and beyond this point, any sequence change that occurred is specific for each branch (species) (Figure 3). The branch connects nodes of the tree and the length of each branch from one node to the next node represents the number of changes that occurred until the next separation (speciation). In the present tree, some nodes show the order and some show family depending on the ancestral

events and speciation that could have occurred (Figure 3). From this, it is very clear that most of the herbage plants belong to the order of Caryophyllales (Figure 3).

4. DISCUSSIONS

The countries that consume maximum herbages include China and India (Garland, 1993). Now-a-days, people from almost all countries consume herbages. But still, there are people who consider eating herbage vegetables is levity while the people who know the real value of consuming herbages are also increasing rapidly. Even the restaurants that intend to serve fresh greens hardly know around 20-40 varieties of herbages that are being cooked and served in various forms globally. But, the remaining herbage vegetables are either unaware or uncommon to most of the people. So, there is an immediate need to have a detailed knowledge of globally available herbage vegetables that not only increase the health of mankind but also leads to an increased income for restaurants that serve these typical foods prepared from numerous herbage varieties.

All the energy we get is from the food we eat. If we eat good food, we can be healthy as diet plays a key role in the prevention and control of various diseases (Burr, 1863). Almost all the herbage vegetables that were listed in Table 1 have therapeutic values and majority of them have antioxidant (Afsheen et al., 2018; Bajpai et al., 2005), anti-inflammatory (Fawole et al., 2010), anticancer (Asadi-Samani et al., 2018) antibacterial and antimicrobial properties in common. So ingestion of herbage vegetables itself protects us from various infections and boosts our immune system (Simonetti, 1990). Some herbage vegetables also show experimentally proved antidiabetic (Lans, 2006), antimalarial, anticholinesterase (Boga et al., 2011), antithrombin (Chistokhodova et al., 2002), hepatoprotective, gynecological problems (Balamurugan et al., 2018), cerebroprotective, etc., roles that prevents us from severe illness and maintains good health.

The tribes from Rampachodavaram forest, East Godavari District; Araku valley, Visakhapatnam district; Parvathipuram, Vizianagaram district; Srisailam, Kurnool district and Tirupati, Chittoor districts of Andhra Pradesh, India eat *Alternanthera sessilis* leaves for better vision; *Aerva lanata* leaves for urolithiasis; *Boerhavia diffusa* leaves for kidney and urinary problems; *Sesbania grandiflora* flowers for curing Madras eye, etc. At the same time, there are several other published and scientifically proved uses of not only these plants but of all the 114 herbage vegetables. For the correct identification of a plant that belongs to the class of herbage vegetables, a detailed and sound knowledge is necessary.

Keeping these in mind, our work shows the scientific and common names of the plants, their edible parts along with their proper identification for the normal people. For scientific identification of the plants, we have constructed an indented type of dichotomous foliar key, leaf morphology-based taxonomic identification key (Figure 2), for the characteristic identification of all the 114 herbage vegetable plants.

Next, to identification, the proper phylogeny and ancestral relationships of those plants are equally important for the researchers and this was attained by constructing the cladogram, a rooted tree (Figure 3). Our cladogram results showed similarity with that of Angiosperm Phylogeny Group (APG) system, a recent system, of classification. The cladogram results showed similarity with our constructed indented foliar key.

Our results also show that the plants belonging to Polypetalae were most commonly used as herbage vegetables and the parts that are edible, other than leaves, include flowers or inflorescence (Figure 1). The number of plants that belong to each herbage part and family was tabulated (Table 1). The present manuscript will be of great use to the people of various scientific fields and a lot of research has to be done on these herbage plants in the fields of biosystematics and

numerical taxonomy.

5. CONCLUSIONS

Herbage vegetables are plants with edible aboveground or aerial parts that include stem, leaves, buds, flowers, and inflorescences along with their modifications. 114 such herbage vegetables were gathered, collected, identified taxonomically by constructing the indented type of dichotomous foliar key and cladogram was constructed to find the phylogeny and ancestral relationships of all the herbage plants. This foliar key and phylogenetic tree help us in the characteristic identification of globally edible herbage plant parts used as vegetables for the well-being of humans.

AUTHORS CONTRIBUTIONS

GBVA selected, collected the data and identified them by constructing indented keys. NR collected the plants, classified them, contributed in experimental design and drafted the manuscript. All authors commented, read and approved the final manuscript.

COMPETING INTERESTS

The authors have had no financial, personal or other relationships with other people or organizations within five years of the beginning of the submitted work that could inappropriately influence, or be perceived to influence, their work. The authors declared that no competing interests exist.

ACKNOWLEDGEMENTS

We are grateful to Dr. Ramakrishna, Director of Sri Satya deva nursery, Kadiyam, East Godavari District, Andhra Pradesh, India (<http://www.srisatyadevanursery.in/index.html>) for supplying us loam soil, pots and the plants. However, this nursery had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

REFERENCES

1. Afsheen, N., Khalil Ur, Rehman, Jahan, N., Ijaz, M., Manzoor, A., Khan, K. M., & Hina, S. (2018). Cardioprotective and metabolomic profiling of selected medicinal plants against oxidative stress. *Oxid Med Cell Longev*, 2018, 9819360. doi: 10.1155/2018/9819360
2. Asadi-Samani, M., Rafieian-Kopaei, M., Lorigooini, Z., & Shirzad, H. (2018). A screening of growth inhibitory activity of Iranian medicinal plants on prostate cancer cell lines. *Biomedicine (Taipei)*, 8(2), 8. doi: 10.1051/bmdcn/2018080208
3. Bajpai, M., Mishra, A., & Prakash, D. (2005). Antioxidant and free radical scavenging activities of some leafy vegetables. *Int J Food Sci Nutr*, 56(7), 473-481. doi: 10.1080/09637480500524299
4. Balamurugan, S., Vijayakumar, S., Prabhu, S., & Morvin Yabesh, J. E. (2018). Traditional plants used for the treatment of gynaecological disorders in vedaranyam taluk, south india - an ethnomedicinal survey. *J Tradit Complement Med*, 8(2), 308-323. doi: 10.1016/j.jtcme.2017.06.009
5. Boga, M., Hacibekiroglu, I., & Kolak, U. (2011). Antioxidant and anticholinesterase activities of eleven edible plants. *Pharm Biol*, 49(3), 290-295. doi: 10.3109/13880209.2010.517539
6. Burr, Fearing. (1863). *The field and garden vegetables of america* (Vol. USA): Crosby and Nichols.
7. Chistokhodova, N., Nguyen, C., Calvino, T., Kachirskaia, I., Cunningham, G., & Howard Miles, D. (2002). Antithrombin activity of medicinal plants from central florida. *J Ethnopharmacol*, 81(2), 277-280.

8. Fawole, O. A., Amoo, S. O., Ndhlala, A. R., Light, M. E., Finnie, J. F., & Van Staden, J. (2010). Anti-inflammatory, anticholinesterase, antioxidant and phytochemical properties of medicinal plants used for pain-related ailments in south africa. *J Ethnopharmacol*, 127(2), 235-241. doi: 10.1016/j.jep.2009.11.015
9. Fredslund, J. (2006). Phy.Fi: Fast and easy online creation and manipulation of phylogeny color figures. *BMC Bioinformatics*, 7, 315. doi: 10.1186/1471-2105-7-315
10. Garland, S. (1993). *The complete book of herbs & spices: An illustrated guide to growing and using culinary, aromatic, cosmetic and medicinal plants*. Rydalmere, NSW, Australia: Frances Lincoln Limited.
11. RAWANKAR, AMOL S., GAJANAN A. WAGH, and JAYANT S. WADATKAR. "DNA barcoding and phylogenetic analysis of *Tyto alba*, *Otus bakkamoena* and *Athene bra-ma* from Indian subcontinent." *International Journal of Zoology and Research (UZR)* 5.5 (2015): 7-14.
12. Griffing, Lawrence R. (2011). Who invented the dichotomous key? Richard waller's watercolors of the herbs of britain. *American Journal of Botany*, 98(12), 1-13. doi: 10.3732/ajb.1100188
13. Hill, A. (1972). *Economic botany* (2 ed.). New Delhi: Tata McGraw-Hill.
14. Lans, C. A. (2006). Ethnomedicines used in trinidad and tobago for urinary problems and diabetes mellitus. *J Ethnobiol Ethnomed*, 2, 45. doi: 10.1186/1746-4269-2-45
15. M. Venkaiah, P. Prayagamurthy, S.B. Padal. (2010). *The useful plants of andhra pradesh*. Visakhapatnam: K Jayalakshmi, ESPEE Printers.
16. Yadav, Deependra, SP Singh, and Sarvesh Singh. "Effect of Foliar Application of Potassium Compounds on Yield and Quality of Ber (*Zizyphus Mauritiana* LAM.) CV. Banarasi Karaka."
17. VISHWAKARMA, SUNIL KUMAR, AMRITA NIGAM, and ATUL SINGH. "Molecular phylogenetic analysis of *Fusarium* isolates causing Pokkah boeng disease in sugarcane based on RAPD marker." *Int J Agricul Sc Res* 6.3 (2016): 177-186.
18. Pandey, B.P. (2005). *Angiosperms; taxonomy, anatomy, embryology (including tissue culture) and economic botany* (Vol. 3): S Chand & company limited.
19. Rao, Rolla Seshagiri. (1999). *Flora of east godavari district, andhra pradesh, india*: ITC BBhadrachalam Paper Boards Limited.
20. Rasajna, BVA Gorthi and Nadella. (2017a). Innovation of multi curative herbal powder: Dasapatrachurnam. [Original Research]. *International Journal of Medicinal Plants*, 111, 812-821.
21. Rasajna, BVA Gorthi and Nadella. (2017b). Taxonomical identification, classification and phenetic relationships of mangroves from coringa sanctuary. [Original Research]. *Journal of Taxonomy*, 108, 113-134.
22. Sreelakshmi, V. V., E. P. M. Sruthy, and J. Shereena. "Relationship between the leaf area and taxonomic importance of foliar stomata." *IMPACT: International Journal of Research in Applied, Natural, and Social Sciences* 2.7 (2014): 53-60.
23. Rimando, T.J. (2004). *Crop science* (Vol. 1). College of Agriculture: UPLB.
24. Sambamurthy AVSS. (2005). *Taxonomy of angiosperms*.
25. Simonetti, Gualtierio. (1990). *Simon & schuster's guide to herbs and spices*: Simon & Schuster, Inc.